In the Claims

Please amend the claims as follows:

Claim 1 (currently amended): A micro-electro-mechanical optical apparatus comprising:

an optical element capable of motion in at least ~~one degree~~ <u>two degrees</u> of freedom wherein the motion in the at least ~~one degree~~ <u>two degrees</u> of freedom is enabled by serpentine hinges configured to enable the optical element to move in the at least ~~one degree~~ <u>two degrees</u> of freedom;

driving elements configured to deflect the optical element in said at least ~~one degree~~ <u>two degrees</u> of freedom to controllably induce deflection in the optical element; and

<u>at least one</u> damping element.

Claim 2 (original): The micro-electro-mechanical optical apparatus of Claim 1 wherein the optical element is constructed of single crystal silicon.

Claim 3 (canceled)

Claim 4 (original): The micro-electro-mechanical optical apparatus of Claim 1 wherein said damping element comprises a damping means.

Claim 5 (original): The micro-electro-mechanical optical apparatus of Claim 1 wherein said damping element comprises a coating of a damping agent applied to the serpentine hinges.

Claim 6 (currently amended): ~~The micro electro mechanical optical apparatus of Claim 1~~ <u>A micro-electro-mechanical optical apparatus comprising:</u>

<u>an optical element capable of motion in at least one degree of freedom wherein the motion in the at least one degree of freedom is enabled by serpentine hinges configured to enable the optical element to move</u>

in the at least one degree of freedom;

driving elements configured to deflect the optical element in said at least one degree of freedom to controllably induce deflection in the optical element; and

damping element;

wherein said damping element comprises the serpentine hinges configured to reduce a magnitude of resonances.

Claim 7 (original): A micro-electro-mechanical optical apparatus as in Claim 1 wherein the optical element includes at least one reflective surface.

Claim 8 (original): A reflector array comprising a plurality of micro-electro-mechanical optical apparatus as described in Claim 2.

Claim 9 (currently amended): ~~A micro-electro-mechanical optical apparatus as in Claim 1~~ A micro-electro-mechanical optical apparatus comprising:

an optical element capable of motion in at least one degree of freedom wherein the motion in the at least one degree of freedom is enabled by serpentine hinges configured to enable the optical element to move in the at least one degree of freedom;

driving elements configured to deflect the optical element in said at least one degree of freedom to controllably induce deflection in the optical element; and

damping element;

wherein the at least one degree of freedom is further enabled by at least one pair of torsional hinges.

Claim 10 (original): A micro-electro-mechanical optical apparatus as in Claim 1 wherein the optical apparatus is incorporated into a wavelength router having an optical cross-connect switch and a wavelength division multiplexer.

Claim 11 (currently amended): A micro-electro-mechanical optical apparatus comprising:

a support structure having a plurality of optical device assemblies formed thereon, wherein the optical device assemblies include:

a movable optical element having an outside edge joined to the support structure using a pair of serpentine hinges;

driving elements positioned such that activation of the driving elements can controllably induce deflection in the movable optical element; and

a damping element;

wherein the serpentine hinges comprise at least one winding with each winding having two arms; and

wherein the movable optical element is formed in a material layer having a layer thickness and the pair of serpentine hinges are formed in the layer.

Claim 12 (canceled)

Claim 13 (currently amended): A plurality of micro-electro-mechanical optical apparatuses as in Claim 11 wherein the movable optical element is formed having [[a]] an element thickness and the pair of serpentine hinges are formed having a hinge thickness and wherein the hinge thickness is thinner than the element thickness ~~of the movable optical element~~.

Claim 14 (original): A plurality of micro-electro-mechanical optical apparatuses as in Claim 11 wherein the plurality of micro-electro-mechanical optical apparatuses are organized in a two dimensional MxN array.

Claim 15 (original): A micro-electro-mechanical optical apparatus as in Claim 11 wherein the movable optical element comprises a mirror having at least one reflective surface.

Claim 16 (original): A micro-electro-mechanical optical apparatus

as in Claim 11 wherein the movable optical element is selected from a group consisting of filters, blockers, gratings and lenses.

Claim 17 (original): A micro-electro-mechanical optical apparatus as in Claim 15 wherein the damping element comprises a damping agent means.

Claim 18 (original): A micro-electro-mechanical optical apparatus as in Claim 15 wherein the damping element comprises a layer of a damping agent formed on the pair of serpentine hinges.

Claim 19 (original): A micro-electro-mechanical optical apparatus as in Claim 18 wherein the damping agent comprises a polymeric material.

Claim 20 (canceled)

Claim 21 (currently amended): A micro-electro-mechanical optical apparatus as in Claim [[20]] 11 wherein each arm of each winding of each serpentine hinge extends in a direction transverse to an axis of rotation defined by the pair of serpentine hinges.

Claim 22 (currently amended): ~~A micro-electro-mechanical optical apparatus as in Claim 20~~ A micro-electro-mechanical optical apparatus comprising:

a support structure having a plurality of optical device assemblies formed thereon, wherein the optical device assemblies include:

a movable optical element having an outside edge joined to the support structure using a pair of serpentine hinges, wherein the serpentine hinges comprise at least one arm; and

driving elements positioned such that activation of the driving elements can controllably induce deflection in the movable optical element;

wherein each arm of each winding of each serpentine hinge extends in a direction transverse to the axis of

rotation defined by the pair of serpentine hinges and wherein each arm is generally contoured to coincide with the shape of the outside edge of the mirror thereby defining circumferentially curved serpentine hinges.

Claim 23 (currently amended): A micro-electro-mechanical optical apparatus as in Claim [[15]] 11 wherein the serpentine hinges comprise at least one winding with each winding having two arms and wherein a proximal portion of each arm of each winding of each serpentine hinge includes a proximal fold which shapes the proximal portion of each arm such that it extends in a direction substantially parallel to an axis of rotation defined by the pair of serpentine hinges.

Claim 24 (currently amended): A micro-electro-mechanical optical apparatus as in Claim [[15]] 11 wherein the shape of the pair of serpentine hinges comprises the damping element.

Claim 25 (currently amended): ~~A micro-electro-mechanical optical apparatus as in Claim 24~~ A micro-electro-mechanical optical apparatus comprising:

a support structure having a plurality of optical device assemblies formed thereon, wherein each of the optical device assemblies includes:

a movable optical element having an outside edge joined to the support structure using a pair of serpentine hinges; and

driving elements positioned such that activation of the driving elements can controllably induce deflection in the movable optical element;

wherein each of the serpentine hinges further comprises:

at least one winding with each winding having two arms with each winding having a length;

one end of each serpentine hinge is connected to the movable optical element and another end of the serpentine hinge is connected to the support structure; and

the length of each winding becomes

progressively shorter from the one end of each serpentine hinge to the another end of each serpentine hinge.

Claim 26 (currently amended): ~~A micro-electro-mechanical optical apparatus as in Claim 24~~ A micro-electro-mechanical optical apparatus comprising:

a support structure having a plurality of optical device assemblies formed thereon, wherein each of the optical device assemblies includes:

a movable optical element having an outside edge joined to the support structure using a pair of serpentine hinges; and

driving elements positioned such that activation of the driving elements can controllably induce deflection in the movable optical element;

wherein each of the serpentine hinges further comprises:

at least one winding with each winding having two arms with each winding having a length;

one end of each serpentine hinge is connected to the movable optical element and another end of the serpentine hinge is connected to the support structure; and

the length of each winding becomes progressively longer from the one end of each serpentine hinge to the another end of each serpentine hinge.

Claim 27 (original): A micro-electro-mechanical optical apparatus comprising:

a support structure having a plurality of bi-axial optical device assemblies formed thereon, wherein the biaxial optical device assemblies include:

a movable frame element having an inside periphery and an outside periphery;

the outside periphery of the movable frame element joined to the support structure using a first pair of serpentine hinges, the first pair of serpentine hinges defining a first axis of rotation about which the

movable frame element can rotate;

a movable optical element having an outside periphery;

the outside periphery of the movable optical element joined to the movable frame element using a second pair of serpentine hinges, the second pair of serpentine hinges defining a second axis of rotation about which the movable optical element can rotate;

frame driving elements positioned such that activation of the frame driving elements can controllably induce deflection in the movable frame element, said deflection inducing rotation of the movable optical element about the first axis of rotation defined by the first pair of serpentine hinges;

optical element driving elements positioned such that activation of the optical element driving elements can controllably induce deflection in the movable optical element, said deflection inducing rotation of the movable optical element about the second axis of rotation defined by the second pair of serpentine hinges; and

a damping element.

Claim 28 (original): A plurality of micro-electro-mechanical optical apparatuses as in Claim 27 wherein a plurality of bi-axial optical device assemblies are organized in a two dimensional MxN array of micro-electro-mechanical optical apparatuses.

Claim 29 (original): A micro-electro-mechanical optical apparatus as in Claim 27 wherein the first axis of rotation about which the movable frame element can rotate is transverse to the second axis of rotation about which the movable optical element can rotate.

Claim 30 (original): A micro-electro-mechanical optical apparatus as in Claim 27 wherein the first axis of rotation about which the movable frame element can rotate is at substantially right angle to the second axis of rotation

about which the movable optical element can rotate.

Claim 31 (original): A micro-electro-mechanical optical apparatus as in Claim 27 wherein the movable optical element comprises a mirror having at least one reflective surface.

Claim 32 (original): A micro-electro-mechanical optical apparatus as in Claim 27 wherein the movable optical element is selected from a group consisting of filters, blockers, gratings and lenses.

Claim 33 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein the damping element comprises a damping means.

Claim 34 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein the damping element comprises a layer of a damping agent formed on at least one pair of the first and second pairs of serpentine hinges.

Claim 35 (original): A micro-electro-mechanical optical apparatus as in Claim 34 wherein the damping agent comprises a polymeric material.

Claim 36 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein each of the first and second pairs of serpentine hinges comprise at least one winding with each winding having two arms.

Claim 37 (original): A micro-electro-mechanical optical apparatus as in Claim 36 wherein each arm of each winding of each of the first pair of serpentine hinges extends in a direction transverse to the axis of rotation defined by the first pair of serpentine hinges, and

wherein each arm of each winding of each of the second pair of serpentine hinges extends in a direction transverse to the axis of rotation defined by the second pair of serpentine hinges.

Claim 38 (currently amended): A micro-electro-mechanical optical apparatus as in Claim 37 wherein each arm of each winding of each first serpentine hinge extends in a direction transverse to the axis of rotation defined by the first pair of serpentine hinges and wherein each arm of the first serpentine hinge is generally contoured to coincide with the shape of the outside periphery of the frame element ~~mirror~~; and

wherein each arm of each winding of each second serpentine hinge extends in a direction transverse to the axis of rotation defined by the second pair of serpentine hinges and wherein each arm of the second serpentine hinge is generally contoured to coincide with the shape of the outside periphery of the mirror ~~frame element~~.

Claim 39 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein each pair of the first and second serpentine hinges comprise at least one winding with each winding having two arms and wherein a proximal portion of each arm of each winding of each serpentine hinge includes a proximal fold which shapes the proximal portion of each arm such that it extends in a direction substantially parallel to the axis of rotation defined by each pair of serpentine hinges.

Claim 40 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein the shape of the pairs of the first and second serpentine hinges comprise the damping element.

Claim 41 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein each of the serpentine hinges further comprise:

the first pair of serpentine hinges comprising:

at least one winding with each winding having two arms with each winding having a length;

one end of each first serpentine hinge is connected to the frame element and another end of the serpentine hinge is connected to the support

structure; and

the length of each winding becomes progressively shorter from the one end of each first serpentine hinge to the another end of each first serpentine hinge; and

the second pair of serpentine hinges comprising:

at least one winding with each winding having two arms with each winding having a length;

one end of each second serpentine hinge is connected to the frame element and another end of the serpentine hinge is connected to the movable optical element; and

the length of each winding becomes progressively shorter from the one end of each second serpentine hinge to the another end of each second serpentine hinge.

Claim 42 (original): A micro-electro-mechanical optical apparatus as in Claim 31 wherein each of the first and second serpentine hinges further comprise:

a first end and a second end;

at least one winding with each winding having two arms with each winding having a length; and

the length of each winding becomes progressively longer from the first end of each serpentine hinge to the second end of each serpentine hinge.

Claim 43 (original): A micro-electro-mechanical optical apparatus comprising:

a support structure having a plurality of bi-axial optical device assemblies formed thereon, wherein the bi-axial optical device assemblies include:

a first movable frame element having an inside periphery and an outside periphery;

a second movable frame element having an inside periphery and an outside periphery;

a third movable frame element having an inside periphery and an outside periphery;

a movable optical element having an outside

periphery;

the outside periphery of the first movable frame element joined to the support structure using a first pair of serpentine hinges, the first pair of serpentine hinges defining a first axis of rotation about which the first movable frame element can rotate;

the outside periphery of the second movable frame element joined to the inside periphery of the first movable frame using a first pair of torsional hinges which defines a first torsional axis of rotation about which the second movable frame element can rotate, the first torsional axis of rotation is substantially parallel to the first axis of rotation about which the first movable frame element can rotate;

the outside periphery of the third movable frame element joined to the inside periphery of the second movable frame using a second pair of serpentine hinges which define a second axis of rotation about which the third movable frame element can rotate, the second axis of rotation being transverse to the first axis of rotation;

the outside periphery of the movable optical element joined to the third movable frame element using a second pair of torsional hinges which defines a second torsional axis of rotation about which the optical element can rotate, the second torsional axis of rotation is transverse to the first axis of rotation and to the first torsional axis of rotation;

first frame driving elements positioned such that activation of the first frame driving elements can controllably induce deflection in the first movable frame element, said deflection inducing rotation of the first movable optical element about the first axis of rotation defined by the first pair of serpentine hinges;

second frame driving elements positioned such that activation of the second frame driving elements can controllably induce deflection in the second movable frame element, said deflection inducing rotation of the second movable optical element about the first

torsional axis of rotation defined by the first pair of torsional hinges;

third frame driving elements positioned such that activation of the third frame driving elements can controllably induce deflection in the third movable frame element, said deflection inducing rotation of the third movable frame element about the second axis of rotation defined by the second pair of serpentine hinges;

optical element driving elements positioned such that activation of the optical element driving elements can controllably induce deflection in the movable optical element, said deflection inducing rotation of the movable optical element about the second torsional axis of rotation defined by the second pair of torsional hinges; and

a damping element.

Claim 44 (original): A micro-electro-mechanical optical apparatus as in Claim 43 wherein the movable optical element comprises a mirror having at least one reflective surface.

Claim 45 (original): A plurality of micro-electro-mechanical optical apparatuses as in Claim 44 wherein the plurality of micro-electro-mechanical optical apparatuses define reflector assemblies and wherein the reflector assemblies are organized in a two dimensional MxN reflector array.

Claim 46 (original): A micro-electro-mechanical optical apparatus as in Claim 43 wherein the movable optical element is selected from a group consisting of filters, blockers, gratings, and lenses.

Claim 47 (original): A micro-electro-mechanical optical apparatus as in Claim 44 wherein the damping element comprises a layer of a damping agent formed on at least one of the first and second pairs of serpentine hinges and first and second pairs of torsional hinges.

Claim 48 (original): A micro-electro-mechanical optical apparatus as in Claim 47 wherein the damping agent comprises a polymeric material.

Claim 49 (original): A micro-electro-mechanical optical apparatus as in Claim 44 wherein each of the first and second pairs of serpentine hinges comprise at least one winding with each winding having two arms.

Claim 50 (original): A micro-electro-mechanical optical apparatus as in Claim 49 wherein each arm of each winding of each of the first pair of serpentine hinges extends in a direction transverse to the axis of rotation defined by the first pair of serpentine hinges, and

wherein each arm of each winding of each of the second pair of serpentine hinges extends in a direction transverse to the axis of rotation defined by the second pair of serpentine hinges.

Claim 51 (currently amended): A micro-electro-mechanical optical apparatus as in Claim 50 wherein each arm of each winding of each first serpentine hinge extends in a direction transverse to the axis of rotation defined by the first pair of serpentine hinges and wherein each arm of the first serpentine hinge is generally contoured to coincide with the shape of the outside periphery of the frame element ~~mirror~~; and

wherein each arm of each winding of each second serpentine hinge extends in a direction transverse to the axis of rotation defined by the second pair of serpentine hinges and wherein each arm of the second serpentine hinge is generally contoured to coincide with the shape of the outside periphery of the mirror ~~frame element~~.

Claim 52 (original): A micro-electro-mechanical optical apparatus comprising in combination:

a support structure;

a movable optical element

at least one pair of serpentine hinges;

driving elements positioned such that activation of the driving elements can controllably induce deflection in the movable optical element;

a damping element; and

the combination comprising means for inducing a damped rotation of the movable optical element about an axis of rotation defined by each of the at least one pair of serpentine hinges.

Claim 53 (original): The micro-electro-mechanical optical apparatus of claim 52 wherein the movable optical element comprises a bi-axial reflector element movable in two substantially perpendicular axes defined by the at least one pair of serpentine hinges wherein the at least one pair of serpentine hinges comprises a first pair of serpentine hinges defining a first axis of the two substantially perpendicular axes and a second pair of serpentine hinges defining a second axis of the two substantially perpendicular axes.

Claim 54 (original): The micro-electro-mechanical optical apparatus of claim 53 wherein a plurality of said movable optical elements comprises a reflector array incorporated into a single reflector array optical switching device.

Claim 55 (original): The micro-electro-mechanical optical apparatus of claim 53 wherein a plurality of said movable optical elements are incorporated into a pair of reflector arrays used in a two reflector array optical switching device.

Claim 56 (withdrawn): A method for forming an array of MEMS optical elements comprises:

providing a single crystal silicon on insulator (SOI) wafer having a layered structure comprising a silicon wafer layer having an internal oxide layer formed thereon and having a device silicon layer formed on the internal oxide layer, wherein a top surface of

the device silicon layer has formed thereon a top oxide layer, and wherein the bottom surface of the silicon wafer layer has formed thereon bottom oxide layer;

forming a bottom photoresist layer on the bottom oxide film layer having openings defining a bottom pocket;

forming a top photoresist layer on the top oxide film layer having openings defining hinge regions and open structures;

first etching to remove the top oxide layer in hinge and open regions defined by the openings in the top photoresist layer exposing a hinge region of the device silicon layer;

forming a second photoresist layer on a top surface of the SO1 wafer, the second photoresist layer patterning the hinge region of the device silicon layer so that a hinge can be formed;

second etching the patterned hinge and open region to remove portions of the device silicon layer forming recessed portions and such that unetched surfaces correspond to a hinge;

removing the second photoresist layer, thereby exposing the underlying top oxide layer as a hard mask layer having openings in the hinge and open regions;

third etching the device silicon layer through the openings in the hard mask wherein the recessed portions are etched until the internal oxide layer is reached, and wherein the unetched surfaces are partially etched leaving a portion of the unetched surfaces in place as hinges, thereby defining hinge thickness;

fourth etching the bottom surface of the SO1 wafer through openings in the bottom oxide layer to remove material from the silicon wafer layer to form a pocket region defining a movable optical element supported by hinges;

fifth etching the SO1 wafer to remove the internal oxide layer in the pocket region; and

forming a reflective layer on at least one surface of the movable optical element.

Claim 57 (withdrawn): The method of Claim 56 further including a sixth etching to remove material from a separation line region thereby enabling the structure to be separated into arrays of a desired size.

Claim 58 (withdrawn): The method of Claim 57 wherein the operation of sixth etching comprises the operations of:

dry etching to remove material from the separation line region;

laser cutting in the separation line region; and

cleaving in the separation line region into separate arrays of desired sizes.

Claim 59 (withdrawn): The method of Claim 57 wherein the operation of sixth etching comprises the operations of:

laser cutting in the separation line region; and

cleaving in the separation line region into separate arrays of desired sizes.

Claim 60 (withdrawn): The method of Claim 57 wherein the operation of sixth etching comprises the operations of:

dry etching to remove material from the separation line region; and

cleaving in the separation line region into separate arrays of desired sizes.

Claim 61 (withdrawn): The method of Claim 57 further comprising:

assembling the separated arrays with another wafer having formed thereon appropriate driving elements and control circuitry, and

packaging the assembled arrays.

Claim 62 (withdrawn): The method of Claim 61 wherein packaging the assembled arrays comprises hermetically packaging the assembled arrays.

Claim 63 (withdrawn): A method for forming an array of MEMS optical elements comprises:

providing a single crystal silicon wafer having top surface and a bottom surface, the top surface having

formed thereon a top oxide layer and the bottom surface having formed

thereon a bottom oxide layer;

forming a bottom photoresist layer on the bottom oxide film layer having openings defining a bottom pocket;

forming a top photoresist layer on the top oxide film layer having openings defining hinge regions and open structures;

first etching to remove the top oxide layer in hinge and open regions defined by the openings in the top photoresist layer exposing a hinge region of the device silicon layer;

forming a second photoresist layer on a top surface of the wafer, the second photoresist layer patterning the hinge region of the device silicon layer so that a hinge can be formed;

second etching the patterned hinge and open region to remove portions of the device silicon layer in a timed etch, thereby forming recessed portions and such that unetched surfaces correspond to a hinge;

removing the second photoresist layer, thereby exposing the underlying layer as a hard mask layer having openings in the hinge and open regions;

top oxide third etching the device silicon layer through the openings in the hard mask wherein the recessed portions are etched in a timed etch leaving a portion of the unetched surfaces in place as hinges, thereby defining hinge thickness;

fourth etching the bottom surface of the SO1 wafer through openings in the bottom oxide layer to remove material from the silicon wafer to form a pocket region defining a movable optical element supported by hinges; and

forming a reflective layer on at least one surface of the movable optical element.

Claim 64 (withdrawn): The method of Claim 63 further including a fifth etching to remove material from a separation line region thereby enabling the structure to be separated

into arrays of a desired size.

Claim 65 (withdrawn): The method of Claim 64 wherein the operation of fifth etching comprises the operations of:

dry etching to remove material from the separation line region;

laser cutting in the separation line region; and

cleaving in the separation line region into separate arrays of desired sizes.

Claim 66 (withdrawn): The method of Claim 64 wherein the operation of sixth etching comprises the operations of:

laser cutting in the separation line region; and

cleaving in the separation line region into separate arrays of desired sizes.

Claim 67 (withdrawn): The method of Claim 64 wherein the operation of sixth etching comprises the operations of:

dry etching to remove material from the separation line region; and

cleaving in the separation line region into separate arrays of desired sizes.

Claim 68 (withdrawn): The method of Claim 64 further comprising:

assembling the separated arrays with another wafer having formed thereon appropriate driving elements and control circuitry, and

packaging the assembled arrays.

Claim 69 (new): A MEMS actuator comprising:

a support structure;

a movable optical element;

a plurality of serpentine hinges extending between the movable optical element and the support structure, each serpentine hinge including a plurality of arms exhibiting a plurality of arm lengths.

Claim 70 (new): The MEMS actuator of claim 69, wherein the arms are curved from a perspective normal to the optical element.

Claim 71 (new): The MEMS actuator of claim 69, wherein each hinge includes a first end connected to the support structure and a second end connected to the movable optical element, and wherein the arm lengths of each hinge become progressively shorter from the first end to the second end.

Claim 72 (new): The MEMS actuator of claim 69, wherein each hinge includes a first end connected to the support structure and a second end connected to the movable optical element, and wherein the arm lengths of each hinge become progressively longer from the first end to the second end.

Claim 73 (new): The MEMS actuator of claim 69, wherein the hinges define at least one axis of rotation, and wherein at least one of the arms extends in parallel with the axis of rotation.